THE PLANNING AND BASIC DESIGN OF ULSAN GRAND BRDIGE

Park, Kyung-Ho
Vice President, Project Director,
Ulsan Grand Bridge Project,
Hyundai Engineering & Construction Co., Ltd.
khpark54@hdec.co.kr

Park, Jong-Hwa
Project Managing Director,
Civil & Environment Division,
Hyundai Engineering & Construction Co., Ltd.
parkjh@hdec.co.kr

Lee, Jung-Han
Chief Engineer,
Ulsan Grand Bridge Project,
Hyundai Engineering & Construction Co., Ltd.
davinci@hdec.co.kr

Kim, Gi-Nam
Senior Engineer,
Ulsan Grand Bridge Project,
Hyundai Engineering & Construction Co., Ltd.
gnkim@hdec.co.kr

Shin, Seoung-Kyun
Vice President,
Structural Division,
Yooshin Engineering Corporation
skshin@yooshin.co.kr

Shin, Sang-Hoon
Associate Director,
Structural Division,
Yooshin Engineering Corporation
shshin@yooshin.co.kr

Lee, Min-Jae
Chief Engineer,
Structural Division,
Yooshin Engineering Corporation
mjlee@yooshin.co.kr

Hwang, Guk-Jin
Chief Engineer,
Structural Division,
Yooshin Engineering Corporation
y12789@yooshin.co.kr

Abstract: *The Ulsan Grand Bridge is a single span suspension bridge which has the main span of 1,150 m. When completed in the end of 2014, the bridge will have the 3rd largest span as single span suspension bridge in the world. This project, promoted as BTO, is made for the bridge owner Ulsan City, by the Hyundai Engineering & Construction Company Consortium. This paper gives brief introduction of planning and basic design of Ulsan Grand Bridge, focusing on the overall structural configurations of the bridge.*

Keywords: Ulsan Harbour, suspension bridge, single-span, tunnel anchorage, A/S method, high strength wire

1. INTRODUNCTION

The Ulsan Grand Bridge is a single span suspension bridge which will span the harbor mouth of Ulsan City in the southeast area of Korea. The bridge has the main span of 1,150 m and the approaching viaducts of 303 m and 355 m to each side of the suspended span as shown in Fig.1. The viaducts are made of traditional steel box girders and prestressed concrete beams. The bridge will have 4 traffic lanes and a 300 m wide navigation clearance of at least 60 m height.
When completed in the end of 2014, the bridge will have the 3rd largest span as single span suspension bridge in the world. This project, promoted as BTO (Build-Transfer-Operate), is made for the bridge owner Ulsan City, by the Hyundai Engineering & Construction Company Consortium.

This paper gives brief introduction of planning and design of Ulsan Grand Bridge, focusing on the overall structural configurations.

Figure 1: Overview view of Ulsan Harbour Bridge

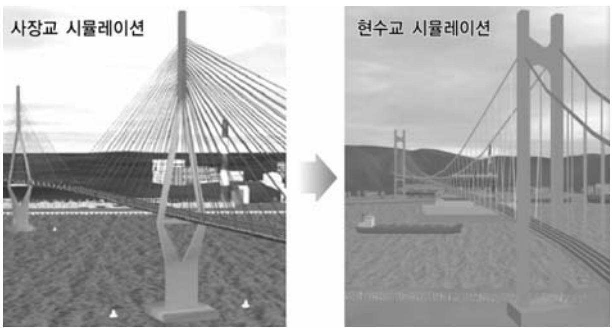
2. PLAN OF THE BRIDGE TYPE AND SPAN

Two conceptual designs for spanning the Ulsan harbor were investigated. The first is a three-span continuous cable-stayed bridge with the center span of 725 m. The second is a single span suspension bridge with the main span of 1,150 m. The second concept was chosen considering the optimum bridge alignment, safety of navigation, the preservation of the natural environment, and construction economics. The followings are brief explanations for the structural characteristics of the Ulsan Grand Bridge.

2.1 Long span bridge enhancing the safety of ship navigation

Ulsan Grand Bridge goes across the 9th dock and Yeompo dock in Ulsan harbour which is a transportation stronghold of Ulsan city. The safety of ship navigation should not be disturbed because the large vessels sail frequently. In the existing plan of the cable-stayed bridge, the pylon on the sea makes a sense of unease when the ship is navigating the route and coming alongside the dock. Especially, during the long construction period, lots of troubles are expected in ship navigation. But, this plan, the suspension bridge with 1,150m main span, can avoid the ocean foundation. There is not any disturbance on the navigation channel and the construction period is relatively short in the sea. And, by the ship navigating simulation, it is confirmed that this plan minimize the harmful influences to the large ships.

(a) navigation channel



(b) simulation

Figure 2: Ship navigation simulation

(a) cable-stayed bridge (b) suspension bridge

Figure 3: Safety of ship navigation

2.2 Landmark of the Ulsan Metropolitan City

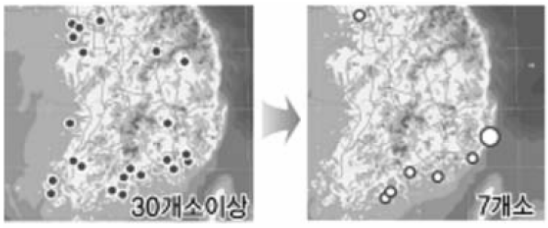
Long span bridges in the world play an important part as a landmark of the city or the country. Just as the Golden Gate Bridge in San Francisco, the Brooklyn Bridge in New York, the Gwangan Bridge in Busan and so on, long span bridge plays a role in not only the transportation structure but also the landmark in the each city. So, Ulsan Grand Bridge also demanded to be a representative landmark with distinguished view in Ulsan Metropolitan City. Among the single-span suspension bridges, Ulsan Grand Bridge is top-ranked in Korea and the third in the world in the aspect of the main span length. In addition to that, numbers of cable-stayed bridge have been built in Korea. In the aspect of either the scale or the rarity, suspension type will be an excellent choice as a new landmark of Ulsan city.

Table 1: Suspension bridges in Korea

No	Name	Span	Main span	Year
1	Gwangyang Br.	3	1,545m	Under construction
2	Ulsan Br.	Single	1,150m	Under design
3	Jeokeum Br.	Single	850m	Under construction
4	Gwangan Br.	3	500m	2002
5	Namhae Br.	3	404m	1973
6	Yeongjong Br.	3	300m	2000

Table 2: Single-span suspension bridges in the world

No	Name	Main span	Country	Year
1	Runyang Br.	1,490m	China	2005
2	Jiangyin yangtze Br.	1,385m	China	1999
3	Ulsan Br.	1,150m	Korea	Under design
4	2nd Bosporus Br.	1,090m	Turkey	1988
5	1st Bosprous Br.	1,074m	Turkey	1973
6	Kurushima 3 Br.	1,030m	Japan	1999



cable-stayed br. suspension br.

Figure 4: Long span bridges in Korea

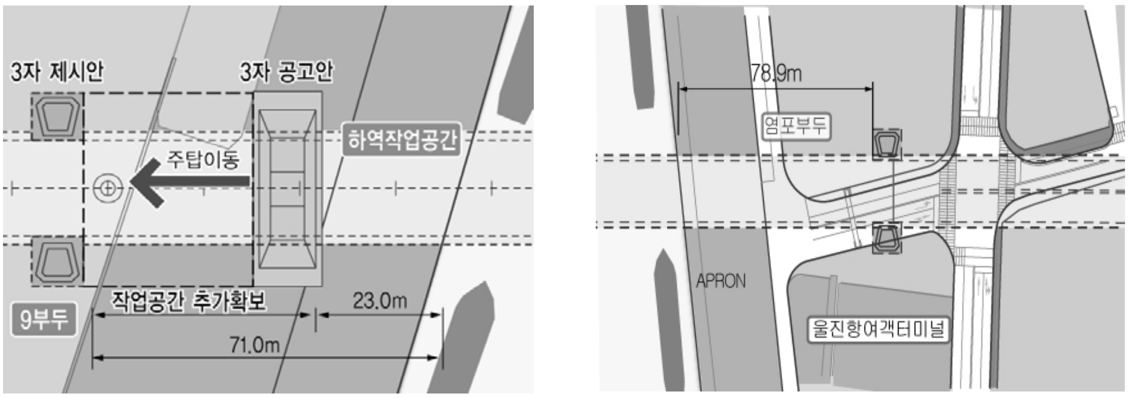
Figure 5: Ulsan Grand Bridge

2.3 Competitiveness of Ulsan Harbour

Many-sided factors are considered in bridge planning. Among them, the position of each pylon is very important because it determines the main span length. It should be decided to keep the efficiency of the harbour serviceability and to improve the economical efficiency.

In the original design of cable-stayed bridge, the pylon #1 in the 9th dock was 23 meters away from anchoring wall. It lowers the harbour operation efficiency due to a small working space. At present, the interference at the loading and unloading yard is relieved because the distance is extended over 71 meters. The pylon #2 in the Yeompo dock is placed outside of the site proposed for an extension work of Yeompo dock not to prevent the harbour operation.

The construction of this bridge will do not interfere with the operation of Ulsan Harbour which is a transportation stronghold. The competitiveness of Ulsan Harbour will be superior to every other harbour.



PY#1 PY#2

Figure 6: Position of each pylon

3. DESIGN OF MAIN STRUCTURAL COMPONENTS

3.1 Streamlined stiffening girder

Ulsan Grand Bridge will be the single-span suspension bridge of 1,150m with streamlined stiffening girder, which has a good aerodynamic stability and light weight as shown in Figure 7. As a result of wind tunnel test, it is stable up to the wind speed of 85m/sec (critical wind speed is 78.1m/sec with safety factor 1.3). Therefore, it can overcome the aerodynamic instability of suspension bridges as shown in Figure 8. For the upper and lower longitudinal ribs of girder, U-shaped ribs are used instead of I-ribs to reduce a weight and increase a stiffness of girder. Additionally, the welding connection will be used instead of bolting with the same reason.

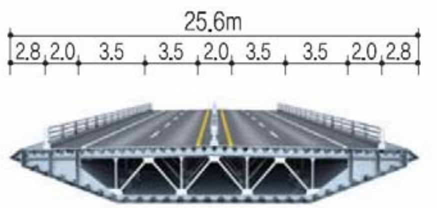


Figure 7: Streamlined stiffening girder

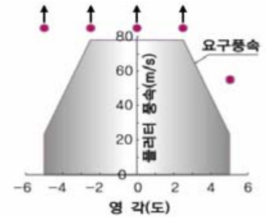
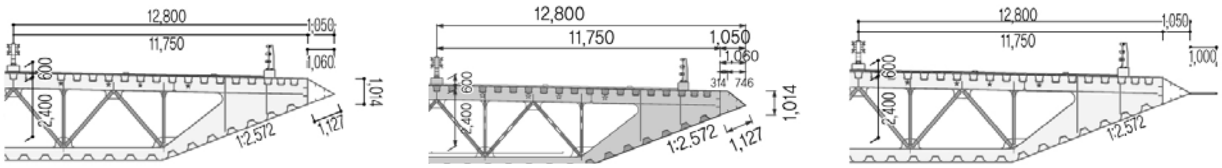


Figure 8: Results of wind test

To investigate the aerodynamic stability of the stiffening girder, the wind tunnel tests have been carried out using three types of sectional models. As a result of the test, in case of section#1, the flutter instability occurs at the angle of attack +2.5 °(Uniform flow and turbulence flow), in cases of section #2, #3, the both of flutter and vortex-induced vibrations did not happen. But, for the future maintenance of bridge, section #2 section is selected as shown in Figure 10.



Section #1 Section #2 Section #3

Figure 9: Stiffening girder sections

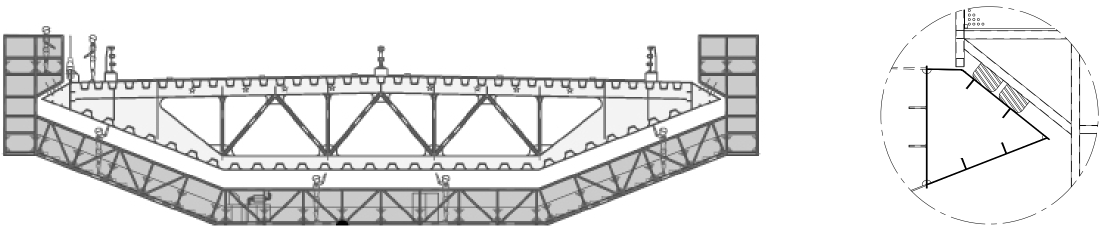


Figure 10: Maintenance equipment

3.2 Cables

The main cable is the most important structural element of a suspension bridge, which transfer the loads to the anchorage through the pylon. For technical as well as economical reasons, air-spinning method has been chosen for this bridge. As repect of main cable strength, 1,760Mpa wire which is used Akashi Kaikyo Bridge(1998), 1,860Mpa wires for the main cable of Kwangyang Bridge which is under consturction, are used , but for the Ulsan Grand Bridge, 1,960Mpa wires will be used at first in the world. By using a high strength wire, drag force is mitigated as a effects of reduced cable weight and section.

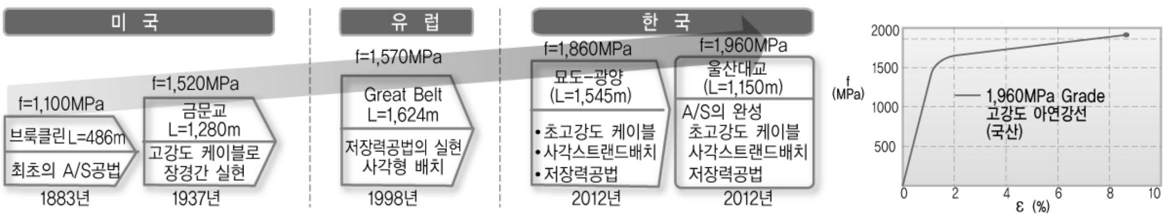


Figure 11: Transition of cable strength

Its main cable consists of 504 bundles of parallel Φ 5.35mm wires and 16 strands for the main span and right side span. But, in case of the left side span, there are 5% of additional tension in comparision with

other spans. Therefore, two Extra strands are used additionally as a repect of economical and strucutral efficiency.

Type			Specifications	
Wire	Maierial		KS D 3059 piano wire rods	
	Diameter		φ=5.35mm	
	Modulus of elasticity		$2.0X10^5$ MPa	
	Tensile strength		1,960 MPa	
	Allowable strength		784 MPa (SF=2.5)	
Cable	Type		Main, Right side	Left side
	Strands		16St	16St+2extra
	Wires		8,064	8,448
	Area		0.18128 mm^2	0.18991 mm^2
	DIa	BeforeWrapping	537mm	550mm
		AfterWrapping	543mm	556mm
		Band	531mm	-
	Unit weight		13.96kN/m	14.62kN/m

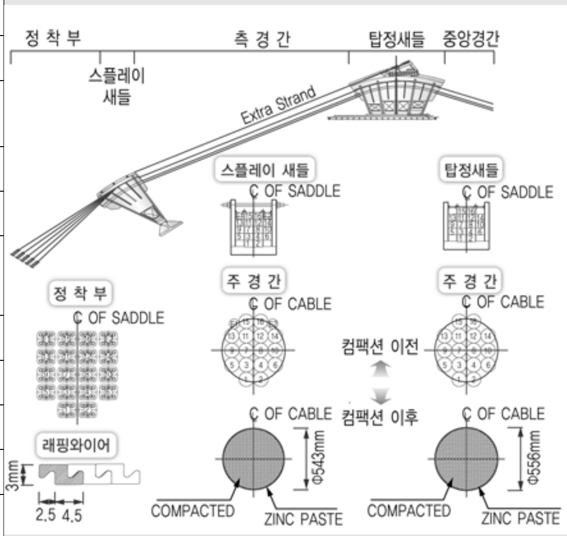
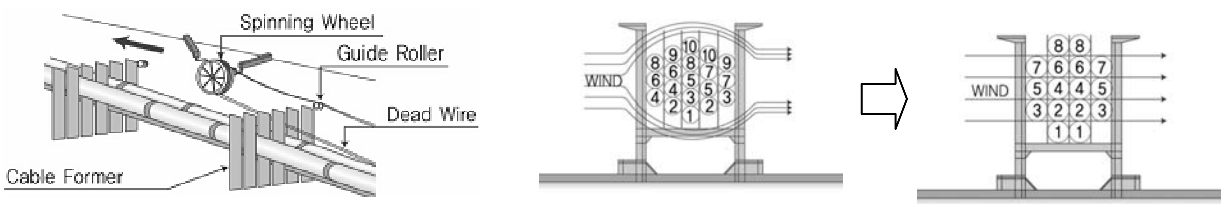


Figure 12: Main cable configuration

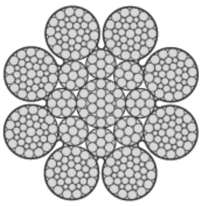
Innovated A/S method with rectangular strand arrangement and low-tension method are adopted in cable construction. In low-tension method, the sag adjustment is controlled strand by strand and the construction speed is promoted because the influence of wind is small by pulling tension at the level of 20%~80%. Shimotsui Seto Bridge, Great Belt Bridge and Gwangan Bridge are constructed by this method. In innovated A/S method, strands are arranged in rectangular form with 16 strands comparing with usual hexagonal form with 19 strands. The number of A/S times is reduced, the sag adjustment becomes easy by the improvement of air permerability and the drainage goes smoothly during the construction.



(a) A/S method (b) rectangular arrangement

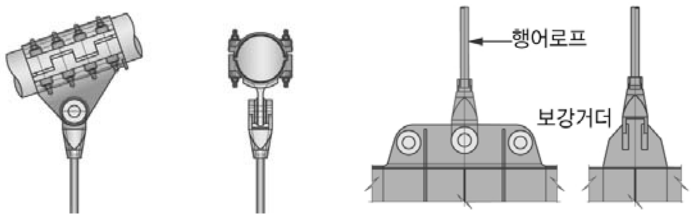
Figure 13: Innovated A/S method

CFRC hanger rope is selected because of a merit in the durability and fatigue. In case of Yeongjong, Kwangan, Sorok and Carquinez Bridge, it was applied as shown in Figure 14. Pin-type connection is apllied due to its simple shape. In case of Sorok, Jeokuem, Akashi, Bosphrous and Severn Bridge, it was adopted as shown in Figure 15.



- fu = 1,610 MPa
- S.F. = 3.0
- E = 140,000 MPa

Figure 14: Hanger rope (CFRC)

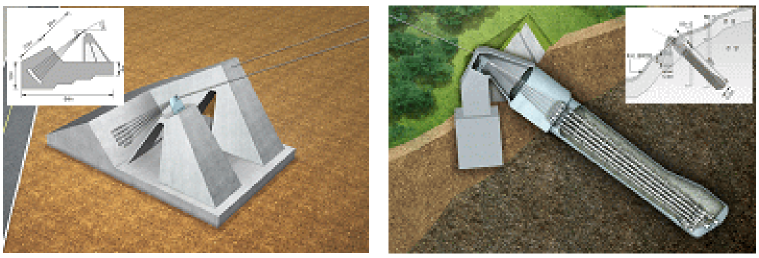


(a) Pin at cable side (b) Pin at girder side

Figure 15: Hanger rope connection (pin-pin type)

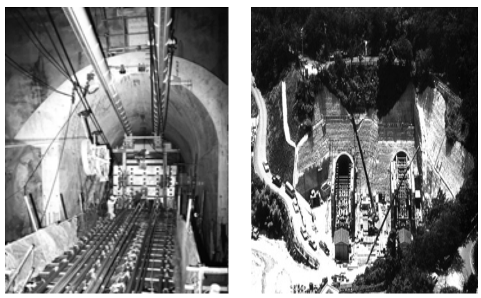
3.3 Anchorage

Ulsan Grand Bridge is an earth-anchored type bridge as usual. In this type, the anchorage is a main structure to resist tension forces generated by cables and to satisfy the bearing capacity of the ground and external stability against the falling and sliding.
The start point anchorage is a gravity- type that makes stability using self-load. It is the most stable structure that has a special foundation shape like stairs for reducing costs. This type is applied to the Gwangan, Namhae and Gwangyang Bridge, and etc. The end point is a tunnel type anchorage that makes stability using shear forces of a steel frame and ground pressures of extension areas, for being constructed on the stiff slope of the Yeompo mountain and this type is eco-friendly to reduce amount of trench work. A tunnel type anchorage is applied to the Shimotsui Seto Bridge and the third Kurushima Bridge.



gravity type (AN#1) tunnel type (AN#2)

Figure 16: type of the anchorage



Shimotsui Seto Kurushima 3

Figure 17: tunnel type cases

Table 3: Anchorage type of the suspension bridge in the South Korea

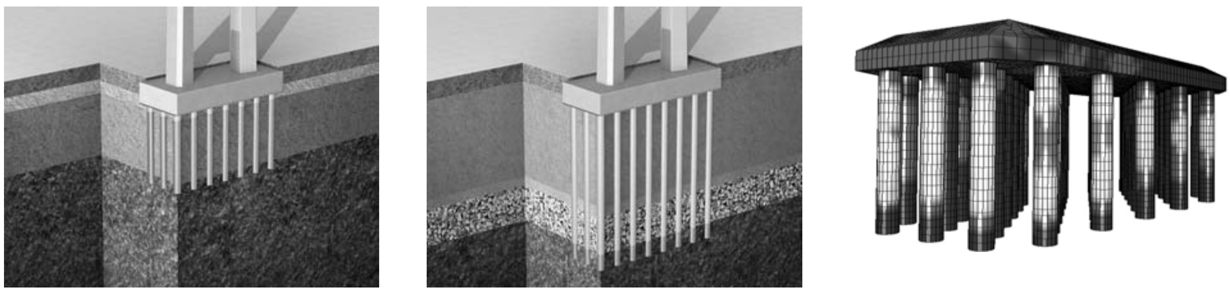
Section		Anchorage Type	Ground Type	Foundation Size	Note
Namhae Bridge	Start End	Gravity	Foundation rock	B x L = 35.8x20 m	H = 23 m
Gwangan Bridge	Start End	Gravity	Foundation rock	B x L = 53.6 x 43.6 m	H = 27 m (Be) H = 35 m (La)
Jeokgeum Bridge	Start	Gravity	Foundation rock	Φ40m	Slurry Wall
	End	Gravity	Foundation rock	B x L = 37.5 x 32 m	Stair type foundation
Gwangyang Bridge	Start	Cavern	Foundation rock	Anchored length 40m	68 Hole
	End	Gravity	Foundation rock	Φ68m	Slurry Wall

3.4 Pylon

Ulsan Grand Bridge has a rahmen type reinforcement concrete pylon with trapezoidal shape. This pylon's shape is decided for considering a structure safety, economical efficiency, durability and management. In the past, pylon of the suspension bridge was mainly made of steel, but nowadays many concrete pylons are being built due to the development of concrete material and construction methods. In the aesthetic point of view, a straight line of pylon is the landmark of the area because of its rising feeling of visual part and the mid-crossbeam is "U" shape that represents the Ulsan city. So, Ulsan Grand Bridge stands out for representing the Ulsan city as shown in Figure 18.

Figure 18: Pylon

In-situ casting pile, D=3.0m, is applied to a pylon foundation for considering the ground and construction conditions. The pylon near-by the 9^{th} dock(PY#1) has 21(3 x 7)piles because its ground is well, and the pylon near-by the Yeompo dock(PY#2) has 24(3 x 8)piles because its ground is soft and foundation rock is placed under 60m as shown in Figure 19.



(a) PY#1 (b) PY#2 (c) Gwangyang Bridge

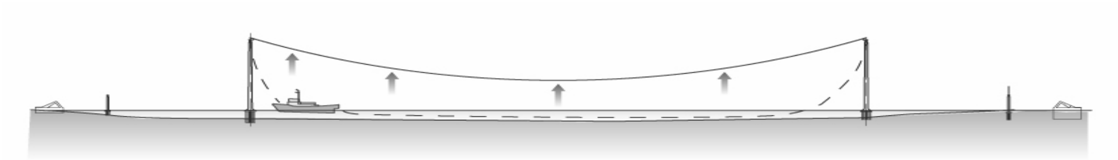
Figure 19: Foundation of pylon

4. Construction plan

Considering the construction conditions, Ulsan Grand Bridge needs to develop methods that minimize occupation at the Ulsan Harbour for the purpose of securing the dock facility yard and ship navigation channel. The construction steps of this bridge are as follows.

① Cosntruction of anchorages and pylons
② Construction of cables
③ Construction of main girders
④ Consturction of subsidiary structures
⑤ Dissolution of construction equipments

pilot rope installation ➡ underwater method



catwalk ➡ aerodynamic stability system

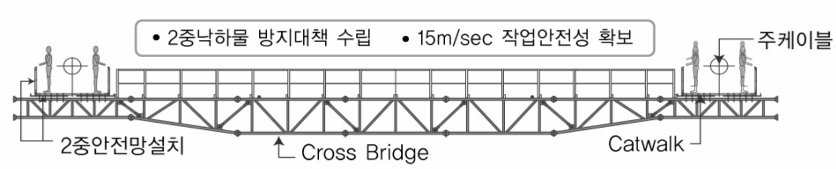


Figure 20. Underwater method and Aerodynamic stability system in catwalk

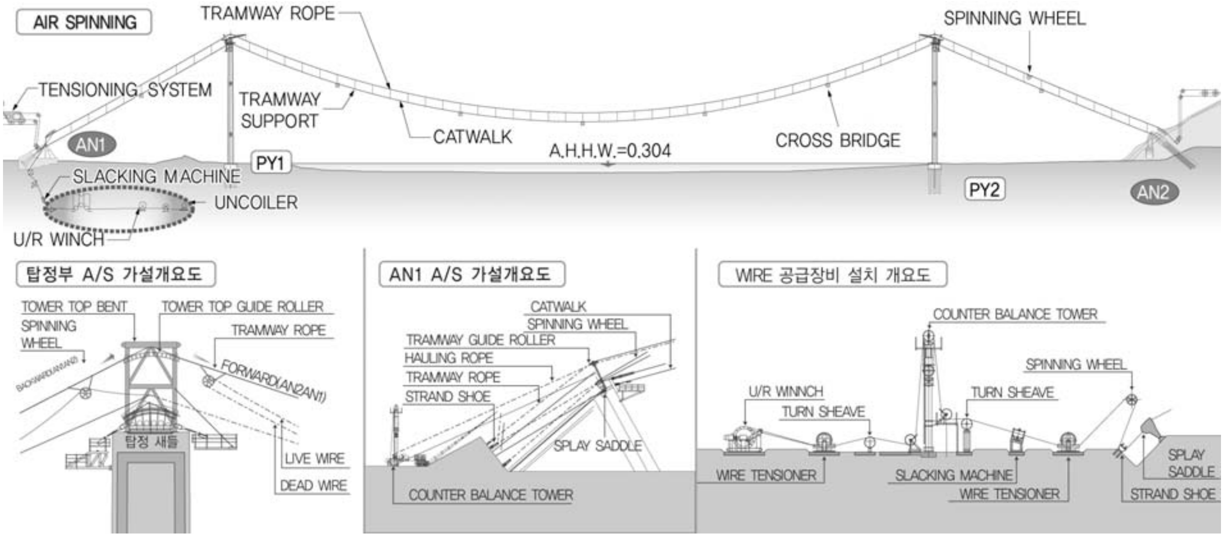
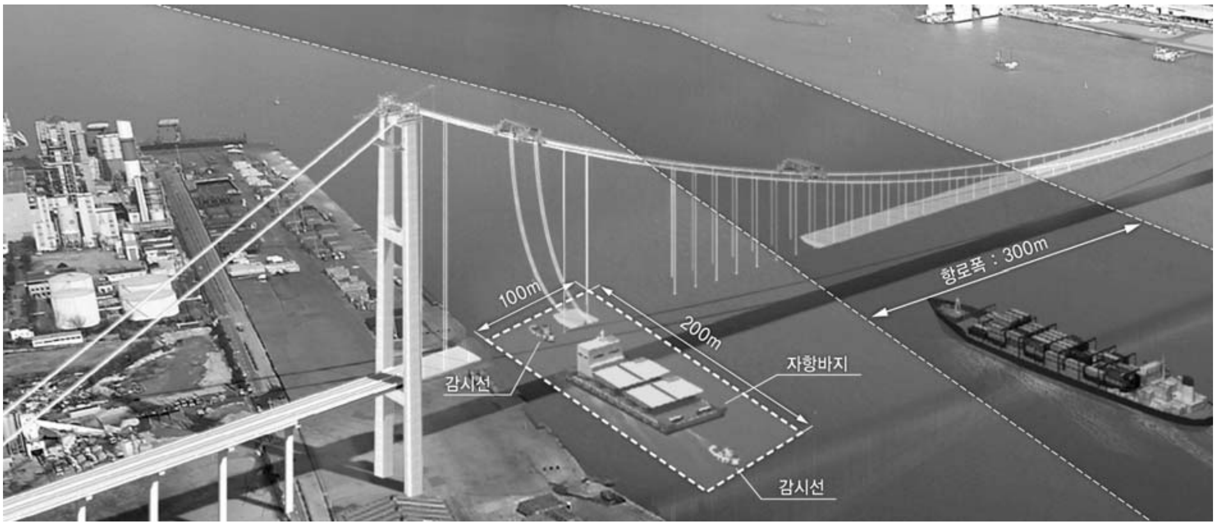
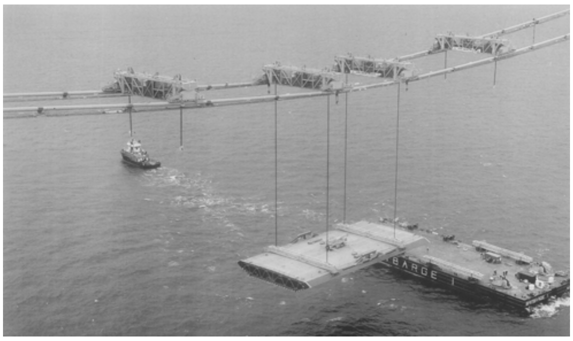


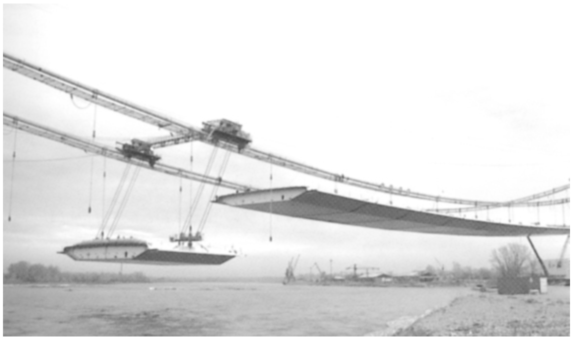
Figure 21: Equipments for A/S method

In-situ casting method using the Auto-climbing form is adopted in pylon construction. The laser and GPS system is applied for controlling the vertical degrees. The pilot ropes, the start of cable-work, cross the ocean under the sea, and this underwater-method can shorten the construction time. For the safety of workers and ships, catwalk system with aerodynamic stability is as shown in Figure 20. The innovated A/S method is selected for main cable construction. And construction equipments are located for

improvement in quality and reduction of construction time as shown in Figure 21. The main girder is moved by a self-propellering barge. Because it can minimize travel time and prevent the accidents when installing girder. Girders will be lifted by small blocks. At the mid area of bridge, the vertical lifting method is applied to shorten travel time and maintains the quality. And at the low depth area and on the ground, the swing method will be adopted as shown in Figure 22.







(a) Lifting method (b) Swing method

Figure 22: Girder installation method

5. Conclusion

During the construction design of Ulsan Grand Bridge, its basic design will be investigated to improve the Hi-tech structural system which can overcome the existing suspension bridge system and applied technique, and will be improved in the construction ability/ safety aspect. For the domestic suspension bridge design and improvement of its construction technique, the utmost effort will be put into its design. Additionally, all of participators of Ulsan Grand Bridge design sincerely promise a completion of its design without a tiny mistake.

REFERENCES

[1] Ulsan Grand Bridge Inc. 2008. Basic design report of Ulsan Grand Bridge (in Korean)